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Performance Evaluation of UFAPB Reactor for Treatment of Domestic Sewage

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***Abstract*: The study was related to the possibility of using UFAPB reactor applied to the treatment of domestic sewage. The effect of Hydraulic Retention Time (HRT) ranging from 12 to 90 hrs and different Organic Loading Rate (OLR) on the performance of the reactor were made. The reactor had an internal diameter of 120mm & height of 600mm resulting in total volume of 6.780 litres & bed volume of 5.99 litres. Gas collecting tank was separately designed with 250mm height & 80mm diameter. The packing media used in the study were coarse aggregate passing through 12.5mm and retaining on 10 mm sieve. Domestic sewage generated from PSG IMS Coimbatore, Tamil Nadu was used as the substrate. The inoculum was prepared using horse dung. To begin with, the reactor was seeded with the inoculums a mixture of horse dung slurry at 24 hrs HRT & left for different HRT. The experiments were performed at HRT of 12, 16, 24, 36, 48, 54, 62, 70, 84 & 90 hrs based on empty reactor volume & the performance of the reactor was evaluated based on the removal of organic matter. The COD & BOD removal efficiency for domestic sewage were in the range of 96.6% to 77.33% & 94.32% to 71.01% respectively. The pH was maintained in the range of 7 to 8.5. The total, volatile, dissolved, suspended & fixed solids removal efficiency were 83.40%, 97.70%, 88.51%, 93.49% & 90.28% respectively, and methane gas emission was also achieved.**

1. INTRODUCTION

The term wastewater is commonly used to describe liquid wastes that are collected and transported to a treatment facility through a system of sewers. Wastewater is generally divided into two broad classifications: domestic wastewater and industrial wastewater. Domestic wastewater comes from communities of homes, businesses, and institutions.

Domestic wastewater is 99.9% water and only 0.1% solids. Most modern wastewater treatment facilities are designed to treat domestic wastewater. Industrial wastewaters that contain high strength waste, toxic waste or acid/caustic waste may have to be pretreated to make them safe to discharge to the collection system. If not, the processes at the wastewater treatment plant receiving the waste could be disrupted. Storm wastewater should be collected and treated (when necessary) separately from domestic and industrial wastewater.

1.1 Domestic waste water

Domestic sewage carries used water from houses and apartments; it is also called sanitary sewage. Many of our daily chores such as bathing, doing laundry, flushing toilets, preparing meals, washing dishes and other activities generate wastewater.

1.2 Background of Anaerobic Treatment System

With the growing population and increasing levels of urbanization and industrialization, the water is becoming a scarce resource and also getting polluted at a very rapid rate. To overcome these, the wastewaters shall be treated properly and maximum reuse/recycling shall be practiced.

These wastewaters can be either treated with aerobic process or anaerobic systems. In the past, aerobic treatment system was favoured as it was considered to be reliable, stable and efficient. However, aerobic treatment systems require large amounts of power for aeration and mixing, whereas power requirement for anaerobic process is relatively low.

Anaerobic digestion is a complex, natural, multistage process. It is an engineered methanogenic process in which decomposition of organic matter under oxygen-free conditions and involves a mixed consortium of different species of anaerobic microorganisms that transform organic matter into biogas. The process is also called biomethanation.

With respect to sustainability and cost effectiveness, anaerobic treatment has a much better score than many alternatives. Particularly, the energy conservation aspect, i.e, avoiding the loss of energy for destruction of organic matter, while energy is reclaimed from the organic waste constituents in the form of biogas, was an important driving force in the development of such systems. At present, other advantages such as the extremely low production of excess sludge and the system compactness are important selection criteria.

2. OBJECTIVES OF THE STUDY

i. Pilot scale study of Upflow Anaerobic Packed Bed reactor (UFAPBR) on treating domestic sewage by using various control factors.
ii. To study the performance evaluation of the UFAPBR for large scale applications.
iii. To feed the reactor with various loading rates & to determine the efficiency of the reactor & methane gas emission.
iv. To determine the stability of the process at short & high HRTs and to examine its treatment efficiencies.

3. MATERIALS & METHODS

3.1. Experimental set up of UFAPBR

Laboratory scale continuous Upflow Anaerobic Packed Bed reactor made of PVC pipe was used in the present study. The reactor had an internal diameter of 120mm and height of 600mm resulting in total volume of 6.78 liter and bed volume of 5.99 liter. The top of the reactor is tightly closed to maintain the stringent anaerobic condition. A gas head space of 100mm was provided on the top of the reactor.

3.2. Components of UFAPB Reactor

i. Feed tank
ii. Feed distribution system
iii. Packing media
iv. Gas collector
v. Sampling ports

3.3. Feed inlet and outlet arrangements

The reactor was fed with substrate from the feed tank to the inlet pipe provided at the bottom of the reactor. The diameter of the feed inlet pipe is 6mm provided upside down. The effluent pipe of diameter 5mm is provided along the side of the UFAPBR reactor about 10mm from the top of the reactor. Constant flow rate in the range of 4 ml/min to12 ml/min were maintained with two adjustable stop rings.

3.4. Sampling ports

Five sampling ports were installed in the UFAPB reactor for the purpose of

i. Feed distribution
ii. Effluent collection
iii. Gas collection

Three sampling ports were installed along the length of the UAPBR at 15 cm intervals, starting from a height of 10 cm above the reactor bottom. The sampling ports of 6mm internal diameter were made of brass nipples was used. The sampling ports were sealed into the wall of the reactor with rubber cork to give tightness. In UFAPBR reactor out of three sampling ports one was below the packing media, one was at packing media and the other above the media fill. This was required to ascertain the role of packing material on reactor performance.

3.5. Support material

The purpose of packing medium is to retain solids inside the reactor, either by the bio-film formed on the surface of the packing medium or by the retention of solids in the interstices of the medium or below it.

The packing media used in the study were aggregate media of round shape which can retain more biomass on surfaces rather than plain surfaces. The packing media have been designed to occupy from the total depth of the UFAPB reactor to approximately 80% of the height of the reactor.

3.6.Substrate

Domestic sewage generated from PSG Institute Of Medical Science Coimbatore, Tamil Nadu was used as the substrate.

3.7.Seeding

Effective microorganisms were used as seed and the reactor was seeded anaerobically with horse dung.

3.8.Biogas outlet

The biogas outlet was provided at the top of the reactor. A gas headspace of 15 cm was maintained. Biogas produced from the reactor will be collected in a gas collection unit.

4. RESULTS AND DISCUSSION

4.1.COD removal efficiency

Normally the COD of domestic sewage ranges between 200 to 700 mg/lt. The COD value is getting decreased for all the HRT'S and those values are compared. The comparison chart shows that the COD removal efficiency is more at maximum HRT's and minimum removal efficiency for lower HRT's. Maximum COD removal efficiency of 96.6% was achieved for HRT of 84 hrs. The removal efficiency for 12 HRT is about 77.33 % due to the loss of biomass during wash out had reduced the COD removal efficiency which is tabulated (Table1).

4.2. BOD removal efficiency

Normally the BOD value of domestic sewage ranges between 100 to 400 mg/lt. The maximum BOD removal efficiency of 91.6 % was achieved at 36HRT which is tabulated (Table 2).

4.3.pH

The pH is a very important variable in the UFAPB reactor process. When the pH in the reactor is too low (<6), the consumption of fatty acids gets strongly inhibited. If the pH is too high (>8.5), the bacteria are limited in their growth by the low concentrations of unionized fatty acids. The pH determines the growth of both methanogens and acidogens. So, the pH of the influent in the inlet was maintained between 7 and 8. The comparison is made between various HRT's pH value. The graph shows only the variation in the pH value among various HRT's. Like other parameters, the pH is not reduced which is tabulated (Table 3 & 4).

4.4. Total Solids

Total solids is a measure of all the suspended, volatile, fixed, and dissolved solids in a sample of waste water. In this study the total solids level was obtained within the limit which is tabulated (Table 5).

Table 1: COD removal efficiency for various HRTs.

HRT(hrs)	Influent (mg/lt)	Effluent (mg/lt)	Removal efficiency
12	3005	681	77.33
16	3005	579	80.73
24	3005	464	84.56
36	3005	397	86.79
48	3005	355	88.19
54	3005	288	90.41
62	3005	243	91.91
70	3005	198	93.41
84	3005	102	96.6
90	3005	299	90.05

Table 2: BOD removal efficiency for various HRTs.

HRT(hrs)	Influent (mg/lt)	Effluent (mg/lt)	Removal efficiency
12	1725	500	71.01
16	1725	366	78.78
24	1725	299	82.67
36	1725	267	84.52
48	1725	232	86.55
54	1725	189	89.04
62	1725	137	92.06
70	1725	109	93.68
84	1725	98	94.32
90	1725	156	90.96

Table 3: pH for short HRTs

Days	12 hrs	16 hrs	24 hrs	36 hrs	48 hrs
1	8.48	8.43	8.41	8.30	8.30
3	8.47	8.40	8.40	8.29	8.27
5	8.43	8.37	8.38	8.26	8.24
7	8.38	8.34	8.32	8.24	8.22
9	8.33	8.31	8.30	8.21	8.20
11	8.29	8.29	8.27	8.18	8.18
13	8.28	8.25	8.25	8.15	8.15
15	8.22	8.30	8.30	8.12	8.07
17	8.32	8.15	8.22	8.09	8.02
19	8.19	8.11	8.17	8.07	7.99
21	8.10	8.07	8.06	7.95	7.93
23	8.01	7.93	7.90	8.08	8.10

Table 4: pH for high HRTs

Days	54 hrs	62 hrs	70 hrs	84 hrs	90 hrs
1	8.20	8.20	8.19	8.00	8.60
3	8.19	8.17	8.11	7.94	8.58
5	8.15	8.13	8.07	7.88	8.41
7	8.10	8.11	8.03	7.76	8.38
9	8.08	8.06	8.00	7.60	8.25
11	8.05	8.01	7.95	7.51	8.12
13	8.01	7.84	7.87	7.44	8.10
15	7.99	7.66	7.77	7.38	7.96
17	7.93	8.00	7.60	7.22	7.85
19	8.11	7.52	8.10	7.16	7.57
21	7.77	7.31	7.44	7.11	7.34
23	7.69	7.11	7.23	7.02	7.12

Table 5: TS, DS, SS, VS & FS values for various HRTs

HRT (hrs)	Influent (mg/lt)	TS (mg/lt)	DS (mg/lt)	SS (mg/lt)	VS (mg/lt)	FS (mg/lt)
12	2995	989	696	294	207	496
16	2995	933	656	288	198	483
24	2995	861	599	279	179	468
36	2995	778	557	267	147	444
48	2995	699	511	258	118	406
54	2995	655	478	241	103	397
62	2995	536	425	222	89	375
70	2995	512	388	210	77	333
84	2995	497	344	195	69	291
90	2995	555	378	223	90	334

CONCLUSIONS

The result obtained from the present laboratory study reveals that the application of UFAPB reactor of can successfully treat domestic wastewater at mesophilic temperature. From the performance evaluation of UFAPB reactor the following conclusions were drawn:

i. A start-up period of 45 days was required to achieve the steady-state phase with an HRT of 84hrs. The results shows that by increasing the HRTs, the treatment of domestic effluent was more effective with gradual increased in COD, BOD & total solids removal efficiency.

ii. At 84 hr HRT, the COD, BOD removal efficiency of 96.6 % and 94.32 %, was obtained respectively. At 84 hr HRT, the TS, SS, DS, FS &VS removal efficiency of 76.03%, 91.63%, 82.73%, 86.30% & 95.59% was obtained respectively.

iii. Since there is a decrease in removal efficiency after 84hrs i.e. 90hrs, it may be conclude that maximum HRT(84 hrs) is the optimum for the bioreactor .

iv. It is evident that the UFAPB reactor can be effectively used for the treatment of domestic wastewater & production of methane gas in developing countries like India, since the system can be designed with relatively high HRT.

SCOPE OF THE PROJECT

i. The study can be performed on the Biogas production for varied HRT and Biogas composition.

ii. Microbial population can be identified in the reactor using Scanning Electron Microscope (SEM).

iii. Kinetic constants studies can be performed using mathematic modelling.

iv. Two stage anaerobic treatment of domestic wastewater using Hybrid Up flow Anaerobic Filter can be studied using other different packing media.

v. Varying the material, size, shape and surface area of the packing media the study can be performed.

vi. Anaerobic process could also be followed by aerobic processes for effluent polishing to utilize the benefits of both processes.

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